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(Distribution and Migration of the Barents Sea Cod,  
Depending Upon its Feeding in Cold Years)

by

T. S. BERGER

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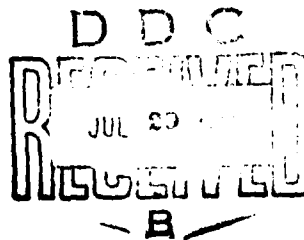
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ABSTRACT  
(Conclusions)

1. The period of fattening, composition of food, intensity of feeding, as well as migration to wintering places in the southern Barents Sea and in the Bjørnøya-Spitsbergen region are diverse. In both of the regions the differences vary from year to year. The fattening period is shorter in cold years than in warm years.

2. In the southern part of the sea, the fattening period begins in January-February, but in the Bjørnøya-Spitsbergen region in May-June. In the southern part of the Barents Sea the most active feeding period is in April-May, but in the northwestern region in June-July. In the southern part one can observe a certain decrease in feeding intensity during June-August. In September, a second increase in the intensity of feeding takes place. In the northwestern region, the cod feeds intensely throughout the summer-autumn period.

In the southern part of the sea, the cod feeds on capelin during the winter-spring period and attains the higher degree of fattening (6.5-8.0%) in April-May. The decrease in the intensity of feeding is associated with transition to other food items, such as euphausiids, ctenophores and shrimps. In the northwestern region, the cod consumes mainly euphausiids during the spring period. The fatness of cod reaches in this season 4.5-6.0%. The maximum fatness (6.5-8.5%) is, in this region, achieved in October as a result of feeding on fishes.

In warm years the cod in both areas departs for wintering grounds in December. In cold years it migrates to the southern part of the sea in November, but to the northwestern sector in October. /71

3. In cold years the cod inhabits the southern region throughout the summer, mainly in the Murman coastal zone. It does not migrate farther than the Goose Bank. In the northwestern region the cod has not been observed north of 79°N (1963) and 77°N (1966).

4. The occurrence of cod on the summer-autumn feeding grounds depends on the distribution of food objects. When feeding on capelin and arctic cod, the cod forms dense and brief concentrations in bottom water even if the water temperature is low.

In the northwestern part of the sea, the spring concentrations of cod on the slopes of Bjørnøya Bank depend on the time of arrival and on the density of euphausiids. The denser the concentrations of euphausiids, the longer stays the cod in the area.

In September-October, by the end of fattening period prior to migration

to wintering grounds, the cod forms dense concentrations.

The fattened cod (7-8% fattening) forms dense schools when migrating southward, usually on the western and southern slopes of Bjørnøya Bank.

5. By analyzing the behavior of cod in cold years (1956, 1963, 1966), it is seen that in 1956 and 1963 the cod reacted swiftly to the cooling and departed far west to wintering grounds; part of the fish even left the Barents Sea. In 1966 the larger portion of schools wintered in the western part of the Barents Sea. These data enable us to assume that the generations that appeared and spent their first years of life under cold conditions, are less sensitive to water temperature changes than the cod born in warm years.

Author

DISTRIBUTION AND MIGRATION OF THE BARENTS SEA COD,  
DEPENDING UPON ITS FEEDING IN COLD YEARS

Regular observations carried out by the Arctic Institute demonstrate that the feeding of cod on fattening grounds changes, depending on special conditions. The study of annual variations in the feeding of cod in the southern part of the sea was launched by V. I. Zatsepin and N. S. Petrova in 1939 [1]. Changes in the feeding of cod during subsequent years are discussed by N. S. Grinkevich (1957) [2].

This paper is based on data collected by the TUNETS, PERSEY RT-106, RT-66, and SEVRYBA in 1956-1966. Data on feeding were processed by the Marine Biological Laboratory, establishing the degree of fattening (ratio of the weight of liver to that of the body, expressed in percentages) during 1956-1963 (by T. K. Sysoyeva) and during 1964-1966 (by O. A. Byzova).

The investigations disclosed that the fattening of sexually immature cod in the southern part of the Barents Sea and in the Bjørnøya-Spitsbergen region does not occur uniformly.

In the southern part of the Barents Sea the cod begins to fatten in February by consuming capelin. The maximum intensity of feeding is reached in March-April so that by the end of April, the degree of fattening is about 6.5-8.0%. When the concentrations of capelin decrease, the cod begins to feed on herring and euphausiids. While doing so, it moves eastward. During this time, the intensity of feeding decreases and the fattening percentage drops to 4.5-5.5.

In September, on Goose Bank and Novozemel'skoye melkovod'ye, the cod feeds intensely on fishes, such as arctic cod, herring, young gadiforms, capelins, etc., and on benthic annuals. By mid-November, its fat percentage increases again, reaching 5.8-6.5. After fattening the cod migrates westward to wintering grounds. The cooling of water undoubtedly induces the migration since the cod continues to feed intensely.

In warm years a large quantity of cod remains in the central region of the sea until schools of capelin arrive. As the latter move southwestward, the cod follows. This actively occurs usually in February. /52

In cold years (1956, 1963, 1966) the cod migrates to the Murman, Finnmarken and Nordkyn banks in January where it continues to feed on capelin, though the intensity of feeding is limited.

At the beginning of winter, the fat content of cod in the southern

part of the sea is always lower than in the Bjørnøya-Spitsbergen region (Fig. 1). No interruption in feeding is observed.

In the Bjørnøya-Spitsbergen region the end of wintering and beginning of fattening occur in April-May in average years, in May-June, sometimes in July, in cold years. At this time euphausiids, the main food item of cod, begin to spawn. Shrimps, ctenophores and themisto are of secondary significance. The quality of spring fattening depends on the quantity of euphausiids. In July-August, when the concentrations of euphausiids became lessened, the cod feeds on shrimps, mysids, crabs and thermistoes.

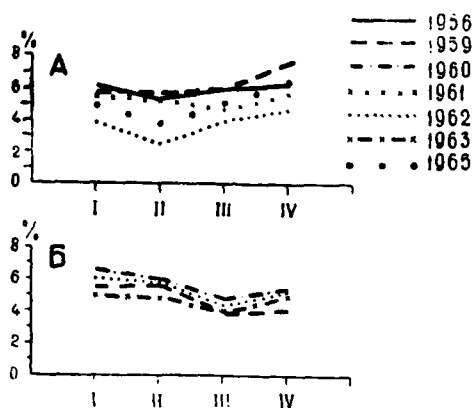


FIG. 1. The Fatness of Cod in Bjørnøya-Spitsbergen Region (A) and in the Southern Part of the Barents Sea (B) For a Series of Years

In September, young commercial fishes arrive in the area, and the cod switches to fish food. Nevertheless, the themisto and benthic crustaceans, such as shrimps and crabs, preserve their significance as food. From September through November the fatness of cod reaches its maximum, 7.5-9.0%. Sometimes, as was observed in 1966, the fatness of cod reaches 10-11%. In November, the intensity of feeding decreases, the cod assembles in dense schools and begins to migrate to wintering places southwest of Bjørnøya. This migration was traced in the autumn and winter of 1963 when the cod, observed in October in the Zuidkapp Trench (Sørkapp) was observed on the western slope of Bjørnøya Bank at the beginning of November. Later it was caught southwest of the area. The same situation was observed in 1966. The fish caught by the TUNETS in the Sørkapp Trench had a high fatness rate, namely 8.6% in October. In November the fishing was active on the western slope of Bjørnøya.

During wintering (up to April) the cod eats little in the Bjørnøya-Spitsbergen region. Its motions are limited and it stays above the bottom. In January-March the cod of the Bjørnøya Bank area is rather scattered, seldom occurring in schools. Only in the winter of 1958 could one observe dense schools of cod up to the end of February.

In order to elucidate the fattening of cod in exceptionally cold years and its effect on the distribution and migration, the data collected during 1956, 1963 and 1966 were analyzed.

In the southern part of the Barents Sea the lowest water temperature /53 in the last three decades was in 1956. The winter cooling was especially pronounced on the shallow eastern region. The summer warming was short and almost did not affect the temperature of bottom water (data collected by the Hydrological Laboratory of PINRO).

Pronounced differences in hydrological conditions in western and eastern regions of the sea affect the distribution of cod in these areas. In summer and autumn, the cod occurs west of the Kola meridian: considerable concentrations of the fish occur in the narrow coastal belt which is relatively warm [3].

During the entire fattening period, the feeding of cod was limited. Even during the capelin season the mean value of stomach content was less than 1.22 or 1.38 (Table 1). Its fat rate was 4.1-6.4%. The feeding did not improve in summer when the cod consumed euphausiids. Despite the abundance of euphausiids in coastal belt, the amount was insufficient for feeding the entire school of cod; 73% of cod stomachs were empty in June. The mean rate of stomach content equalled 1.22, 0.66 in August and 0.55 in September. The fat content was similarly low in these areas: 3.7% in July, 3.0% in November (Table 2).

Small schools of cod were observed in the central region. Here it fed on euphausiids but at a more intense rate than in the coastal belt. In September the mean value of stomach content was 1.44-1.65; by the end of October the fat percentage of individuals 50-70cm long increased to 5.0-5.8%. On the Goose Bank the quantity of cod was small. Here it consumed capelin and arctic cod.

In the southern part of the Barents Sea, the cod did not form large schools in summer.

The cod began to migrate to wintering grounds by the end of November. It moved southward, continuing to feed and forming small schools from Goose Bank to the Murman banks.

Thus, the behavior of cod in the cold 1956 can be characterized as follows: a limited feeding on capelins in the spring, occurrence in coastal belt during the summer-autumn period, low percentage of fat and early departure for wintering grounds. The bulk of catches consisted of the 1950 generation.

In 1963 the water temperature in the upper 200m layer of the Kola cross section was lower than in 1956 (Table 3). This was true of all months of the year. The cooling also involved the northwestern part of the sea, which was not observed in 1956. In the Nordkapp-Bjørnøya sector the temperature of the upper 200m layer was by 0.3° below the temperature in 1956.

The cooling that began by the end of 1962 stimulated the departure of large sexually immature cod for the western region (NW slope of Murman Bank, Murman Tongue and Nordkapp Bank). In the central region one could observe only small cod, 46-50cm long, in February. They were actively feeding on capelins. By the end of February, the fatness of cod on the northern slope of Murman Shoals equalled 5.3%.

Capelin arrived late at the Murman coast. The first concentrations were observed on Rybach'ya and Kil'dinskaya banks by mid-April. By the end of April and in May small cod, in limited numbers, arrived here. By the end of April their fat percentage reached 6.5%. They consumed mainly capelin.

However, the bulk of fishes were observed west of 30°E where the capelin did not occur. Therefore, the fat content of cod was low during this period (2.4% in June). The eastward migration of cod that had wintered in western region began in July, whereas in average years the migration begins by the end of May. The meeting between the cod schools moving eastward and capelin leaving the coastal belt was brief (less than a month). By the end of July the fatness of cod did not exceed 3.4-4.3% (Table 4).

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The greater portion of cod schools moved coastward, as in 1956, where the water was warmer. Here the cod remained throughout the summer, its feeding rate being slow. Its fatness equalled 4.0% in August, 3.6% in October.

The small groups of cod that moved eastward, following capelin reached the southern slope of Goose Bank in August. Here dense concentrations were formed despite a low (+0.4°) water temperature. The migration of cod from the Murman Bank to Goose Bank was evidenced by samples of marked individuals (Fig. 2). The movement was extremely rapid (less than a month), mainly through the middle layers. Trawls did not catch any samples.

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Table 1

The Mean Value of Cod Stomach Content in 1956  
by Months

Regions	Index of stomach content	Number of stomachs							
		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Northwest	0	58	40	23	6	9	17	18	36
	1	39	45	58	59	31	68	70	61
	2	2	8	18	32	25	14	10	2
	3	1	7	1	3	35	1	2	1
	4	—	—	—	—	—	—	—	—
Mean value of stomach content.		0,46	0,82	0,97	1,32	1,86	0,99	0,96	0,68
West	0	No data					15	13	
	1						65	51	
	2						15	22	
	3						5	14	
	4						—	—	
Mean value of stomach content.							1,10	1,37	
Near west	0	28	31	43	49				
	1	27	29	26	18				
	2	27	29	26	17				
	3	15	10	4	12				
	4	3	1	1	4				
Mean value of stomach content.		1,38	1,21	1,04	1,22				
Central region	0	No data					5	19	21
	1						59	65	56
	2						23	13	19
	3						13	3	4
	4						—	—	—
Mean value of stomach content.							1,44	1,0	1,06
Coastal region	0	No data				42	52	17	
	1					50	42	62	
	2					8	5	16	
	3					—	1	5	
	4					—	—	—	
Mean value of stomach content.						0,66	0,55	1,09	

### Fatness of Cod in 1956 by Months

[illegible]

Table 3  
Temperature Anomalies in 0-200m Layer by Hydrological Cross Section\*

1964	III		XXIX		VI		VIII		X		1963		III		XXIX		VI		VIII		X		1966		III		XXIX		VI		VIII		X				
	2-6	7-12	1-4	4-8	1-6	1-4	4-8	1-6	1-4	4-8	2-6	7-12	1-4	4-8	2-6	7-12	1-4	4-8	1-4	4-8	1-6	1-4	4-8	2-6	7-12	1-4	4-8	1-4	4-8	1-6	1-4	4-8	1-6				
I	-0.5	-0.5	-0.6	-0.9	-0.8	-0.6	-0.9	-0.6	-0.6	-0.6	I	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	I	-1.1	-1.0	-1.2	-1.5	-1.3	-2.0	-1.5	-1.3	-2.0	-1.5	-1.3	-2.0		
II	-0.3	-0.5	-0.8	-1.1	-0.9	-1.0	-0.9	-1.0	-0.9	-1.4	II	-1.0	-0.9	-1.4	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-1.4	-1.6	II	-1.5	-1.1	-1.2	-1.5	-1.1	-1.2	-1.5	-1.1	-1.2	-1.5	-1.1	-1.2		
III	-0.2	-0.4	-0.7	-1.2	-0.8	-0.7	-1.2	-0.8	-0.7	-1.2	III	-1.1	-1.3	-1.0	-1.8	-1.3	-1.0	-1.8	-1.3	-1.0	-1.8	-1.5	III	-1.5	-1.3	-1.4	-1.5	-1.3	-1.4	-1.5	-1.3	-1.4	-1.5	-1.3	-1.4		
IV	-0.8	-0.2	-0.6	-0.8	-0.5	-0.7	-0.8	-0.5	-0.7	-1.0	IV	-1.1	-1.0	-1.0	-1.9	-1.0	-1.0	-1.9	-1.0	-1.0	-1.9	-1.3	IV	-1.5	-1.6	-1.5	-1.6	-1.6	-1.5	-1.6	-1.4	-1.6	-1.5	-1.6	-1.4	-1.6	
V	-0.7	0.1	-0.6	-1.0	-0.5	-0.6	-1.0	-0.5	-0.6	-1.0	V	-1.2	-1.0	-0.7	-1.6	-1.0	-0.7	-1.6	-1.0	-0.7	-1.6	-1.3	V	-1.6	-1.4	-1.6	-1.3	-1.6	-1.4	-1.6	-1.4	-1.6	-1.3	-1.6	-1.4	-1.6	
VI	-0.2	0.0	-0.6	-1.0	-0.5	-0.6	-1.0	-0.5	-0.6	-1.0	VI	-0.8	-0.9	-1.0	-1.6	-0.9	-1.0	-1.6	-0.9	-1.0	-1.6	-1.2	VI	-1.4	-1.4	-1.3	-1.4	-1.3	-2.3	-2.4	-1.3	-2.3	-2.4	-1.3	-2.4	-1.3	-2.4
VII	0.1	-0.1	-0.5	-0.8	-0.6	-0.4	-0.8	-0.6	-0.4	-0.8	VII	-0.6	-0.9	-1.2	-1.5	-0.9	-1.2	-1.5	-0.9	-1.2	-1.5	-1.4	VII	-0.6	-0.7	-1.4	-2.0	-2.2	-1.6	-2.0	-2.2	-1.6	-2.0	-2.2	-1.6	-2.0	
VIII	0.1	-0.1	-0.6	-0.8	-1.0	-0.8	-1.0	-0.8	-1.0	-0.8	VIII	-0.4	-0.9	-0.9	-1.6	-0.9	-0.9	-1.6	-0.9	-0.9	-1.6	-1.4	VIII	-0.3	-0.4	-1.3	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0
IX	-0.1	-0.1	-0.7	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	IX	-0.2	-0.7	-0.9	-1.2	-0.7	-0.9	-1.2	-0.7	-0.9	-1.2	-1.4	IX	-0.7	-0.5	-1.3	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0
X	-0.4	-0.1	-0.9	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	X	+0.1	-0.3	-0.2	-0.8	-0.3	-0.2	-0.8	-0.3	-0.2	-0.8	-1.4	X	-0.9	-0.4	-1.7	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0
XI	0.3	0.2	-0.7	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	XI	+0.2	+0.2	+0.2	-0.1	+0.2	+0.2	-0.1	+0.2	+0.2	-0.1	-1.3	XI	-0.7	-0.7	-1.4	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0
XII	-0.2	0.1	-0.5	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	XII	0.0	+0.1	-0.4	-1.3	0.0	+0.1	-0.4	-0.6	-0.4	-1.3	-1.4	XII	-0.6	-0.6	-1.1	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0
Year-ly	-0.2	0.1	-0.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	Year-ly	-0.5	-0.8	-0.8	-1.4	-0.5	-0.8	-0.8	-0.8	-0.8	-1.4	-1.4	Year-ly	-1.0	-1.0	-1.3	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0	-1.2	-2.4	-2.0

\*III---Nordkapp-Bjørnøya, XXIX---N branch of Nordkapp Current; VI---Kola meridian (main branch of Murman Current); VIII---Kharlovskiy cross section; 1-4 stations---Coastal branch of Murman Current; 4-8 stations---main branch of Murman Current; X---Main branch of Murman Current across the north central region

\*III--Nordkapp-Bjørnøya, XXIX--N branch of Nordkapp Current; VI--Kola meridian (main branch of Murman Current); VIII--Kharlovskiy cross section; I-4 stations--Coastal branch of Murman Current; 4-8 stations--main branch of Murman Current; X--Main branch of Murman Current across the north central region

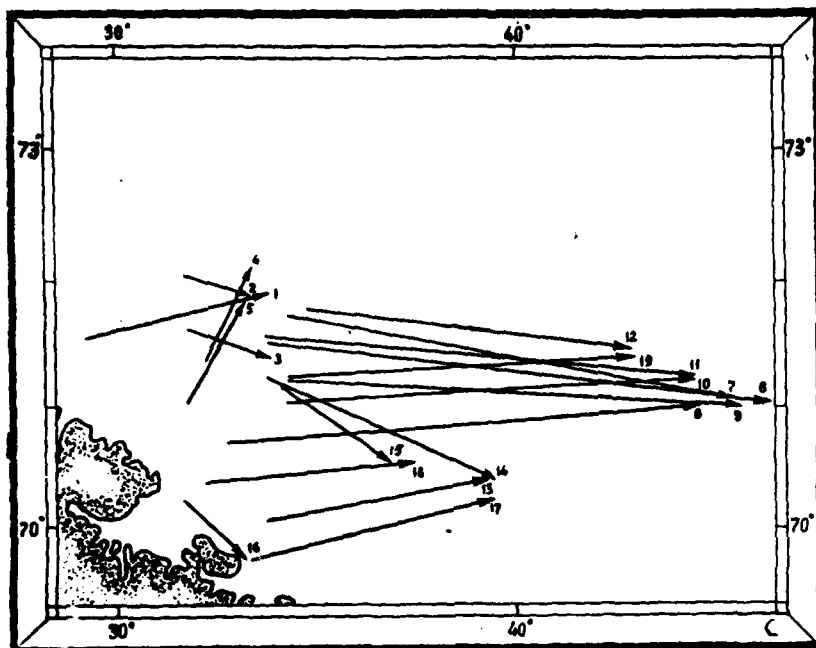


FIG. 2. Migration of Banded Cod Eastward in July-September Period of 1963.

No.	Date of banding	Date of catching
1	22.IV.63 r.	7.VII.63 r.
2	4.V.63 r.	11.VII.63 r.
3	1.VI.63 r.	3.VII.63 r.
4	23.V.63 r.	13.VII.63 r.
5	5.V.63 r.	13.VII.63 r.
6	6.V.63 r.	11.VIII.63 r.
7	2.VII.63 r.	12.VIII.63 r.
8	5.VII.63 r.	13.VIII.63 r.
9	1.VII.63 r.	14.VIII.63 r.
10	1.VII.63 r.	21.VIII.63 r.
11	3.VII.63 r.	22.VIII.63 r.
12	6.VII.63 r.	27.VIII.63 r.
13	10.IV.63 r.	5.IX.63 r.
14	2.VII.63 r.	5.IX.63 r.
15	6.VII.63 r.	7.IX.63 r.
16	15.VII.63 r.	10.IX.63 r.
17	9.V.63 r.	9.IX.63 r.
18	14.VII.63 r.	22.IX.63 r.
19	1.VII.63 r.	27.VIII.63 r.

Table 4

## Fatness of Cod in 1963 by Months

Region	Size Group cm	Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.	
		quan- tity	%	quan- tity	%	quan- tity	%	quan- tity	%	quan- tity	%	quan- tity	%	quan- tity	%	quan- tity	%
Northwest	41-50	24	4.3	45	1.6			79	3.5	61	5.7			55	6.6	1	8.3
	51-60	57	3.8	46	2.1	No		98	3.6	101	5.9	No		139	6.9	23	6.5
	61-70	17	3.9	6	2.9	data		57	3.4	64	5.4	data		71	6.1	30	6.9
West		98	3.9	97	2.2			234	3.5	226	5.9			265	6.5	63	6.9
	41-50	No data						41	3.6	36	3.2					17	4.2
	51-60			44	2.3	41	2.3	63	3.4	43	3.1	25	4.0	No		44	5.3
Near West	61-70			8	2.3	8	2.3	36	3.9	15	2.9	12	5.9	data		25	5.8
						93	2.4	140	3.6	94	3.1	91	5.3			86	5.5
	41-50	33	6.5	123	6.1	23	4.5	39	4.0	No data							
Coastal	51-60	44	5.3	88	5.6	56	4.1	79	4.4								
	61-70	14	4.3	40	6.3	53	4.4	60	4.5								
		91	5.2	251	6.0	132	4.3	168	4.3								
Central	41-50	33	6.5	33	6.3	No data				80	3.8			38	3.4		
	51-60	34	5.3	30	5.5					59	3.5	No		28	3.3	No	
	61-70	14	4.3	28	6.0					20	5.3	data		24	3.8	data	
Central		81	5.8	91	6.0					159	4.0			90	3.6		
	41-50	No data								30	4.4					85	5.1
	51-60									33	4.0	No				68	5.4
Central	61-70									20	4.6					17	5.3
										83	4.3					170	5.3

Feeding on capelin, arctic cod, herring and young gadiforms on the slopes of Goose Bank, and later on the Central Bank, the fatness reached 5.3% in November.

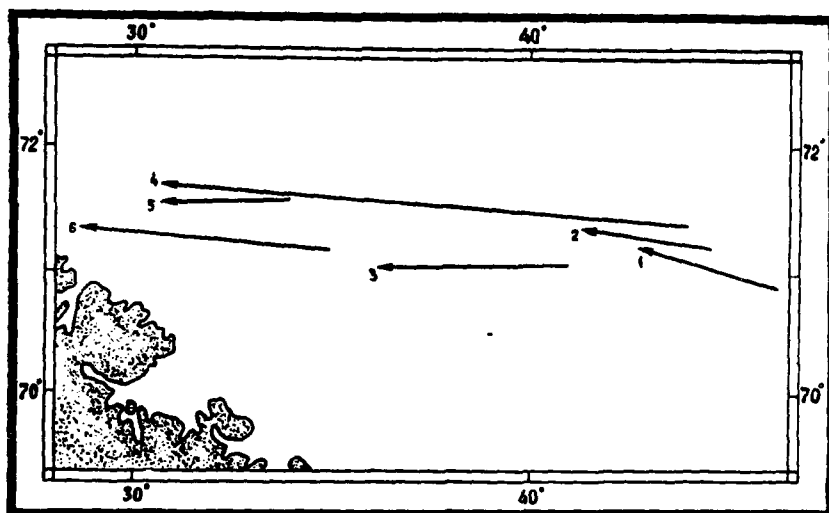


FIG. 3. Migration of banded Cods in November-December 1963.

No.	Date of banding	Date of catching
1	17.VIII.63 r.	19.XI.63 r.
2	16.VIII.63 r.	1.XII.63 r.
3	23.X.63 r.	23.XII.63 r.
4	16.VIII.63 r.	27.XII.63 r.
5	3.VII.63 r.	26.XII.63 r.
6	6.VIII.63 r.	31.XII.63 r.

By mid-November, the cod moved en masse with the main axis of the current. The marked samples that were retrieved confirm the trend (Fig. 3). The samples marked during 16-18 August on Goose Bank were caught in November-December in the north-central region and on the northwestern slope of Murman Bank. While on the move, the cod fed on its young, herring, euphausiids. In central region the stomach content index was 1.06, in coastal belt 1.98 (Table 5).

In December, the fish continued to travel westward, and by the end of the month they appeared in the Murman Tongue, north of Finmarken Bank and in Norway Trench. A small quantity of cod remained in the central region. In January-March 1964, a large number of cod left the boundaries of the Barents Sea.

Table 5

The Mean Value of Cod Stomach Content by Months  
in 1963

Region	Index of stomach content	Number of stomachs in %							
		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Northwest	0	39	82	42	17	12	8	21	36
	1	23	10,8	29	25	30	26	32	16
	2	21	5	22	36	34	33	26	47
	3	14	2	6	18	20	22	16	0,7
	4	3	0,2	1	4	4	11	5	0,3
Mean value of stomach content.		1,19	0,27	0,95	1,49	1,72	2,02	1,52	1,32
West	0	No data				8	12		44
	1					14	14		38
	2					33	43		9
	3					25	26		5
	4					20	5		4
Mean value of stomach content.						2,35	1,98		0,87
Near West	0	8	41	42	24	No data			
	1	7	11	16	27				
	2	15	16	21	26				
	3	27	15	12	19				
	4	43	17	9	4				
Mean value of stomach content.		2,9	1,56	1,5	1,4				
Central	0	No data				25	36	8	46
	1					28	53	4	20
	2					30	7	48	18
	3					10	4	34	9
	4					7	—	6	7
Mean value of stomach content.						1,46	0,64	2,26	1,11
Coastal	0	No data				39	32	13	10
	1					23	25	25	53
	2					25	21	26	30
	3					9	12	23	7
	4					4	10	13	
Mean value of stomach content.						1,16	1,43	1,98	1,34

The year 1963 has the following properties: the feeding of cod on capelin was limited because the boundaries of their temporary habitats did not coincide. The largest portion of the fish remained in the coastal belt throughout the summer. The feeding in summer was restricted. As a result, the fatness percentage was low. The cod departed for wintering grounds in November, spending the winter west of the Kola meridian. The bulk of catches consisted of 1958 and 1959 generations.

In 1966 the upper 200m water layer was colder than in 1963 (Table 3). The cooling involved the entire sea; it was especially pronounced in the eastern part of the sea when in June-August the temperature anomalies in Kharlovskiy cross section reached  $-2.4^{\circ}$  in the coastal branch of current and  $-2.0^{\circ}$  in the main branch.

In January and February the cod occurred in the western region (NW slope of Murman Bank, Demidov and Nordkyn banks and in the Murman Tongue), where it fed on shrimp, young perch and capelin. The cod was observed at that time in the central region and on the eastern slope of Murman Bank. The bulk of the school consisted of individuals 50-55cm long, i.e., the 1959-1960 generations of cod.

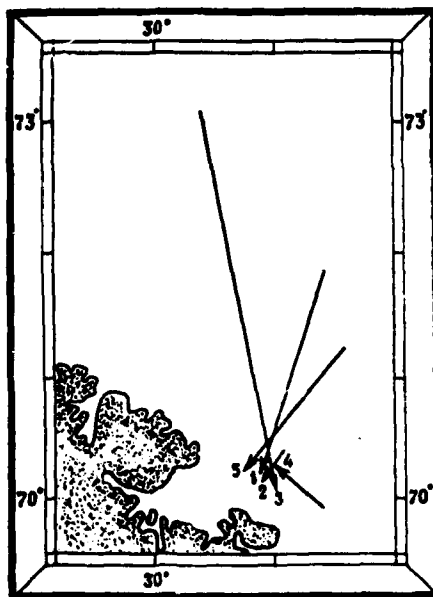


FIG. 4. Migration of banded Cod to Rybach'ya banka in March 1966.

No.	Date of banding	Date of retrieval
1	25.XII.65 r.	21.III.66 r.
2	2.III.66 r.	13.III.66 r.
3	5.II.66 r.	14.III.66 r.
4	2.III.66 r.	23.III.66 r.
5	22.III.66 r.	10.III.66 r.

The cod began to feed intensely on capelin in March on Rybach'ya banka where schools of cod converged from the western area, except for the Nordkyn Bank sector (Fig. 4). In April-May the cod continued to feed intensely as it traveled to Finmarken Bank and the Norwegian Trench (Fig. 5). The mean index of stomach content was 2.86 (Table 6). The fatness reached its maximum value, 7.3%.

In contrast to other cold years, the migration of cod eastward via the coastal branch of the current was observed in June. The cod that was marked in April on Rybach'ya banka was caught in June on Kil'dinskaya banka and in the western coastal region (Fig. 6). As fishes arrived from the Norwegian Trench, the cod concentrations on Finmarken Bank increased. In June the cod continued to consume capelin, herring and euphausiids, but the mean index of stomach content and fatness decreased (Tables 6, 7).

In June the cod began to move with the main branch of the current. Small schools were observed on the northeastern slope of Murman Bank and on the northern slope of the Murman Shoal.

A certain quantity of fishes, mainly of small size, migrated still farther east. Thus, on the western slope of Goose Bank the concentrations of cod were sizeable by the middle of the month. During summer the cod fed on euphausiids, shrimp and arctic cod. In October, 87% of food was made up of herring (Table 8). By the beginning of November, the fatness of cod inhabiting the central region reached 7.5% /64

The schools of cod consisting mainly of small individuals, 35-45cm long (Fig. 7), stayed in coastal sectors throughout the summer. The fish was well distributed along the branch of the current from Rybach'ya banka to Kaninskaya banka, feeding mainly on euphausiids. In November, the fatness reached 5.6-5.8% (Table 7).

The cod began to migrate westward and southwestward in the second half of November. Concentrations of large individuals, 65-75cm long, were observed on Demidovskaya banka on the northern slope of the Murman Shoal and in the western coastal sector (Zapadno-Pribrezhnyy rayon).

Table 6

Mean Index of Stomach Content in Cods by Months  
in 1966

Region	Index of stomach content	Number of stomachs in %							
		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Northwest	0	29	62	29	6	33	4	40	45
	1	26	18	30	12	43	22	18	31
	2	26	10	23	30	15	32	20	21
	3	14	7	13	31	4	34	12	2
	4	5	3	5	21	5	8	12	1
Mean value of stomach content.		1,4	1,7	1,15	2,49	1,05	2,2	1,42	0,83
West	0	No data				20	16	26	27
	1					36	21	20	42
	2					32	29	30	16
	3					12	19	14	8
	4					—	15	10	7
Mean value of stomach content.						1,36	1,96	1,62	1,26
Near West	0	8	41	35	21	No data			
	1	7	24	27	40				
	2	20	16	17	19				
	3	21	10	9	13				
	4	44	9	12	1				
Mean value of stomach content.		2,86	1,22	1,36	1,45				
Central	0	No data				17	9	4	22
	1					32	22	8	19
	2					29	38	23	30
	3					14	20	49	24
	4					8	11	16	5
Mean value of stomach content.						1,64	2,02	2,65	1,71
Coastal	0	No data				21	16	19	13
	1					42	24	27	27
	2					19	31	27	32
	3					11	21	16	22
	4					7	8	10	6
Mean value of stomach content.						1,41	1,81	1,69	1,71



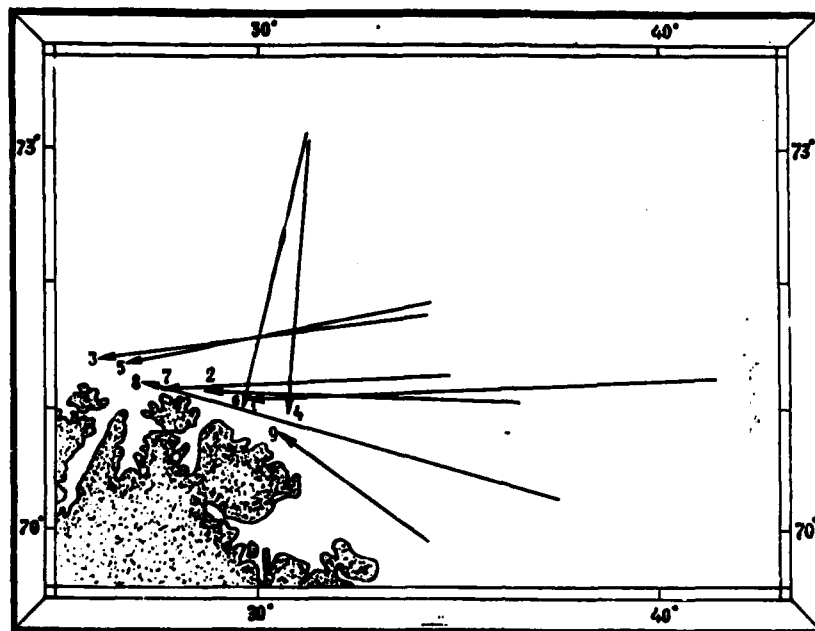


FIG. 5. The banded Cod Following Capelin to the Norwegian Coast in April 1966.

No.	Date of banding	Date of retrieval
1	21. XI. 65 r.	8. IV. 66 r.
2	26. XII. 65 r.	17. IV. 66 r.
3	26. XII. 65 r.	18. IV. 66 r.
4	5. II. 66 r.	22. IV. 66 r.
5	25. XII. 65 r.	20. IV. 66 r.
6	5. II. 66 r.	21. IV. 66 r.
7	22. II. 66 r.	9. IV. 66 r.
8	16. XII. 65 r.	13. IV. 66 r.
9	16. III. 66 r.	16. IV. 66 r.

In December large-sized cod was observed on the Nordkyn Bank. The individuals whose length ranged from 40 to 50cm remained in coastal areas, and continued to forage actively on euphausiids and sea perch. In January 1967 the fatness of the cod increased to 7.2%. /65

Thus, in 1966 the feeding of cod on capelin was very intense. The peak of intensity was reached in February-March, which was not observed in 1956 and 1963.

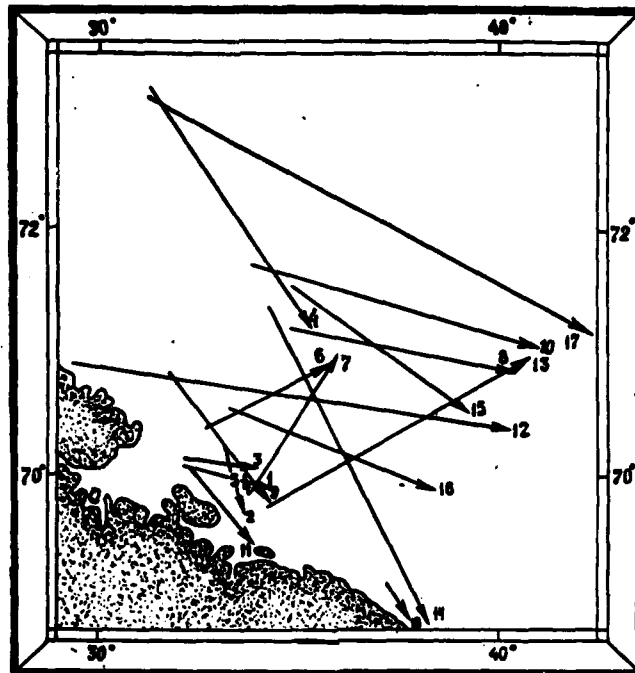


FIG. 6. Migration of banded Cod Eastward  
in June-September 1966

No.	Date of banding	Date of retrieval
1	9.IV.66 r.	16.VI.66 r.
2	22.II.66 r.	23.VI.66 r.
3	9.IV.66 r.	13.VI.66 r.
4	5.II.66 r.	8.VII.66 r.
5	29.VI.66 r.	1.VII.66 r.
6	5.III.66 r.	4.VII.66 r.
7	29.VI.66 r.	4.VII.66 r.
8	22.II.66 r.	28.VII.66 r.
9	29.VI.66 r.	3.VII.66 r.
10	22.II.66 r.	28.VII.66 r.
11	9.IV.66 r.	6.VIII.66 r.
12	4.IV.66 r.	10.VIII.66 r.
13	29.VII.66 r.	11.VIII.66 r.
14	18.I.66 r.	16.VIII.66 r.
15	15.XII.65 r.	18.VIII.66 r.
16	2.III.66 r.	22.VIII.66 r.
17	5.II.66 r.	17.IX.66 r.
18	VIII.66 r.	14.IX.66 r.

Table 8  
Occurrence of Various Food Items in Stomachs of Cod, % of the Number  
of Examined Stomachs

Year	Month	components																	
		Coastal region						West region						Central region					
		eupha- lids	shrimp	amphi- pods	cod	perch	capelin	arctic cod	her- ring	others	eupha- lids	shrimp	amphi- pods	cod	perch	capelin	arctic cod	her- ring	others
1956	VIII	59	6,6	—	1	—	—	—	—	4	—	—	—	—	—	—	—	—	—
	IX	8,4	5,8	0,9	1	—	—	—	—	35	29	—	19	—	—	32,4	—	—	—
	X	15	10	1,5	4	—	—	—	—	20	47	14	5,5	23	—	—	—	—	—
	XI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1963	VIII	8	1,0	4	3,3	—	—	0,2	19	29,2	9	16	6	2,9	—	28	0,2	0,2	3,8
	IX	20	4	5	12	—	—	—	14	13,9	7	9	24	29	—	14	4	14	19,3
	X	17	16	6	22,1	—	—	—	24	28,5	2	18	4	8	0,75	—	—	6	24
	XI	21	2	7	44	—	—	—	9	17	1	16	2,5	22	—	4	7	0,8	16
1966	VIII	41	9	11	4	0,2	—	—	4	33	50	12	2	2	—	6,3	—	0,1	35,3
	IX	42	8	7	3	0,2	0,2	1	7	58,8	16	41	0,5	0,4	2,7	9	—	0,1	42,8
	X	20	2	4	0,6	11	—	—	9	64,2*	2	40	8	1	42	13	—	—	28,5
	XI	45	9	5	0,2	30	—	—	3	56	22	26	—	—	34	—	—	—	59

\*More than half was made of ctenophores.

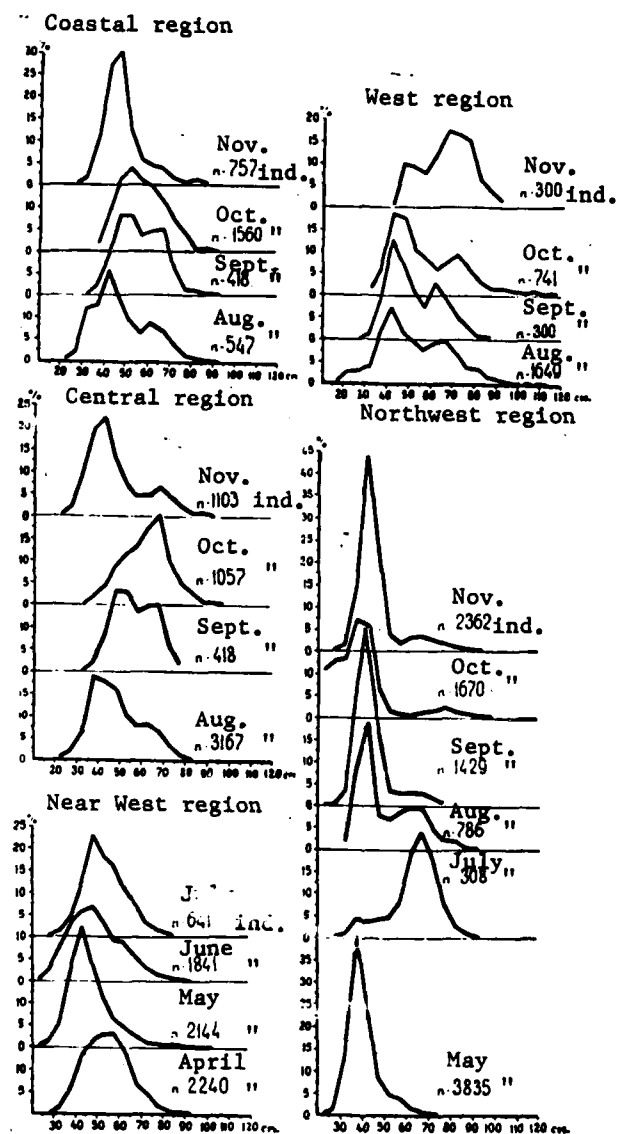


FIG. 7. Size Composition of Cod in % by Months

The first schools of cod migrating eastward were noted in June. The migration reached its peak in July. On the entire route, from the Murman Bank to the Goose Bank, mobile concentrations of cod were observed in July and August. The schools occurred in the coastal belt throughout the summer.

Westward movement began in November, when the fatness of cod reached 5.8% to 7.5%. The samples were represented by the generations of 1962, 1963, 1961, and 1960.

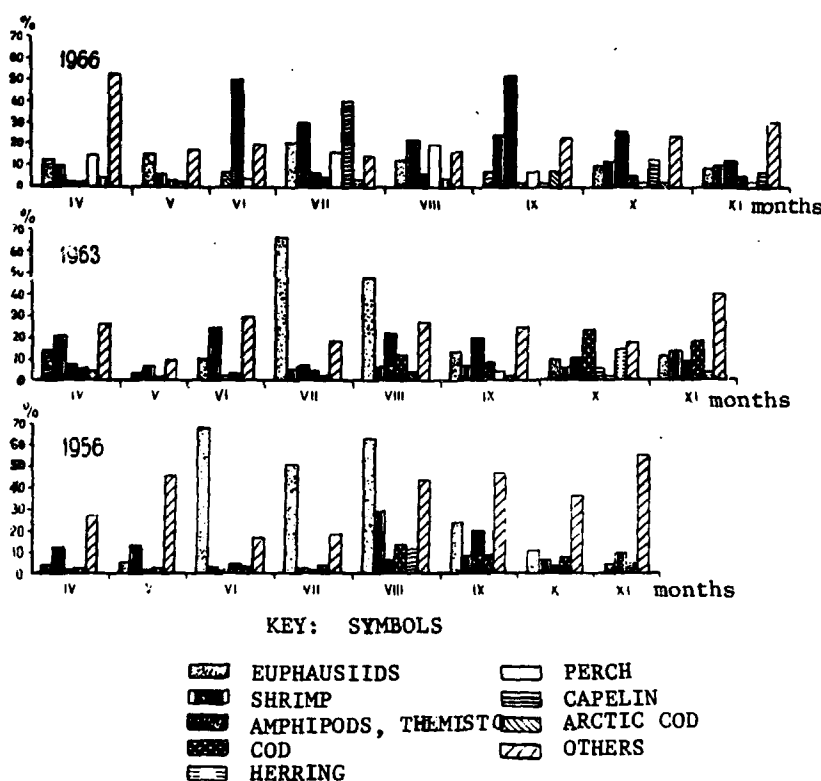


FIG. 8. Occurrence of Various Food Items in the Stomachs of Cod Sampled in Northwest Region

One of the features of 1966 was that the cod was feeding extremely intensely in the coastal belt in November and December, reaching a high percentage of fat in January 1967. Another typical feature of the year was that the large-size fishes did not form concentrations when leaving the central region for the Nordkyn Bank area.

Cooling in the Bjørnøya-Spitsbergen region was not sharp in 1956. The cod began to feed actively on the western slope of Bjørnøya Bank in June when euphausiids appeared in large numbers here. The frequency of their occurrence in cod stomachs reached 67% (Fig. 8). In July the cod began to leave the western slope of the bank for northern and northeastern regions of the Sørkapp Trench and West Spitsbergen. In the latter area the cod continued to feed intensely on euphausiids. At that time the percentage of empty stomachs reached minimum value, 6. The stomach content index equalled 1.32 (Table 1). /69

In August, the best feeding grounds were the Hopen Island area and on the Persey vozvyshennost' (Highland) where the cod arrived from the eastern slope of Bjørnøya Bank. Here the cod consumed mainly capelin. The mean index of stomach content increased to 2.2, but the fatness in individuals 61-70cm long equalled 6.9%.

The cod began to move southward in the last ten-day period of November. In December large schools of the fish were observed on the western slope of Bjørnøya Bank.

In 1963 the influx of warm water by the Spitsbergen Current sharply decreased. As a result, the cod spent the winter in more southern areas. The slopes of Bjørnøya were almost deserted in winter. The feeding of cod in euphausiids began later than in 1956. In July the occurrence of euphausiids in the stomachs of cod foraging on the western slope of Bjørnøya equalled 66%. The mean index of stomach content was 1.49. In August the fatness increases from 3.5% (in July) to 5.9%. During August the cod moved northward and northeastward; namely, along West Spitsbergen to 79°N, and via the Sørkapp Trench to 20°E. In September the intensity of feeding increased rapidly (the mean stomach content index being 2.2). It consumed cod less than one-year old which was brought en masse into the area. In October the fatness increased to 6.9%. The fattened fish assembled in dense schools and by the end of the month began to migrate southward. In November the schools reached the western slope of Bjørnøya Bank.

In May 1966, the first concentrations of cod were noted on the southern slope of Bjørnøya Bank. The fish was actively feeding on euphausiids, entering waters with low temperature (0.3-0.9°). This school spent winter in the area mentioned; 60% of the school was made up of the

rich 1963 generation. The greatest number of cod was about 30-40cm long. In addition to euphausiids, the cod consumed young perch, cod and gadoid fishes. Its fat content was great, 5.9%. The maximum fatness, 6.0%, was reached in cod 41-50cm long.

In June-July, the concentration of cod increased on the western and southern slopes of Bjørnøya Bank as large cod arrived from the south (Fig. 7). The cod was actively feeding on euphausiids, shrimp, ctenophores, young cod, perch and capelin. The mean stomach content index reached 2.49. With the second half of July, the cod began to migrate north, and their concentrations in the Bjørnøya Bank region decreased.

In August-September the cod inhabiting the southern sector of the West Spitsbergen region and the Sørkapp Trench continued to feed mainly on small cod (30-40cm); larger individuals, 65-70cm long, were eaten less often. The major food items were themisto, amphipods, shrimp and young perch. The fatness of small cod was very great, equalling 8.1% by the end of August. Nevertheless, the cod continued to feed actively in September (the mean stomach content index was 2.2). In the Sørkapp Trench area the feeding intensity of cod decreased in October (40% empty stomachs). The highest degree of fatness was attained by the small cod (50cm long), which made up the bulk of catches. The fatness of cod 51-60cm long equalled 8.3%. /70

In the second ten-day period of November the first schools began to migrate south from the western slope of Bjørnøya Bank. Their fatness equalled 8.2%. Individuals 60-65cm long predominated. By the end of the month, the density of schools increased as more cod arrived from northern areas, mainly medium long and small individuals. In December the cod sojourning on the western and southern slopes of Bjørnøya Bank were very fat, but they ate little.

Thus, in 1956 the fattening of cod inhabiting the northwestern region of the Barents Sea began in June and continued throughout the summer. It started on the western slope of Bjørnøya Bank and continued in the Sørkapp Trench and off West Spitsbergen, i.e., in Hopen Island and Persey Elevation area, as the fish moved northward. Southward migration began by the end of November. The fatness percentage by the end of the year was low. The school consisted mainly of generations born in 1948, 1949 and 1950.

In 1963 the cod wintered in more southern areas than in preceding years; evidently, in Kopytovo area because the fish was not noted on the slopes of Bjørnøya Bank in February-March. The northwestern area was visited only by small schools of cod. The fattening of cod on the western slope of Bjørnøya Bank began in July, a month

later than in 1956. By the end of August and in September the cod fed mostly on its own young in the northwestern sector. Nevertheless, the fatness did not exceed 6.9% by the end of October. The southward migration of cod was noted by the end of October. The 1957 and 1958 generations prevailed.

In 1966 we encountered numerous cod of the 1963 generation in northwestern area. Its fattening on the western slope of Bjørnøya Bank began in May and continued throughout the summer. The greatest degree of fatness was reached in October. The fatness slightly exceeded that encountered in 1956 and 1963. The cod occupied a rather limited area and the feeding grounds had the smallest size in comparison with preceding years. The school consisted mainly of the 1963 and 1964 generations.

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